Frequency Shift Keying Demodulation Methods for Wireless Biomedical Implants

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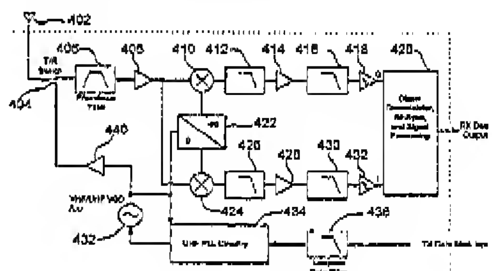
Maysam Ghovanloo and Khalil Najafi

Facts:

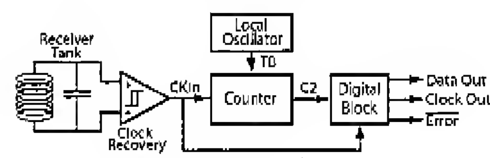
1. All implantable electronic devices need to be wireless to eliminate the risk of infection or patient discomfort resulted from transcutaneous wires breaking the skin barrier.
2. Neuroprosthetic devices that substitute sensory modalities such as cochlear or retinal implants require a wide bandwidth in several Megabits per second (Mbps) range to communicate with a large number of neurons though multiple channels at high stimulus rates.
3. Traditional wideband wireless communication methods require high frequency carrier signals in 100s of MHz or even GHz range to achieve several Mbps data rates.
4. Utilizing high frequency carrier signals in 100s of MHz range through inductive links across the skin is not feasible because they are absorbed in the tissue (> 90% water), and they are above the self resonance frequency of the coupled coils.
5. There is a need for a data modulation/demodulation mechanism that can achieve high data rate in several Mbps range, while keeping the carrier frequency low within 1~25 MHz range.
6. The new modulation/demodulation mechanism should be extremely simple to minimize power consumption and the number of off-chip components that are needed in this low-frequency range of RF signals, while maintaining a wide bandwidth.
7. The new modulation/demodulation mechanism should be extremely safe to detect and notify the external part of the system for a retransmission in the presence of any possible errors.
8. Unlike prior arts, Ghovanloo's novel pcFSK demodulator has all of the above requirements.

Key Differences:

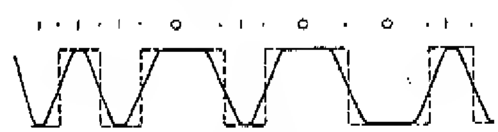
1. Thompson's ordinary "RF" demodulator, which is based on down-converting the RF carrier signal requires five filters (406, 412, 416, 426, and 430), which consume power and occupy a large area. He suggests using FBARs. But those require special designs and processing steps.
2. Ghovanloo's "digital" FSK demodulator does not need a down-converter or ANY filters. Because it can directly convert the incoming carrier signal to digital data bit stream. Hence it can be implemented in a low-cost standard CMOS process.
3. Young's FSK modulation scheme assigns half a cycle to each bit '0' or bit '1'. Therefore, the bit duration for 1's is different from '0's, and the resulting data bit stream will not have a constant rate.
4. Ghovanloo's FSK modulation assigns two full cycles of f_0 to bit '0' and one full cycle of f_1 to bit '1'. Further, it chooses $f_0 = 2f_1$. Therefore, the bit duration for 1's is exactly the same as '0's, and the resulting data bit stream will have a constant rate.
5. Ghovanloo's FSK modulation method with $f_0/f_1 = 2$ is totally different from Tajima's method in which $f_1/f_2 =$ 11MHz/2.3MHz = 5.



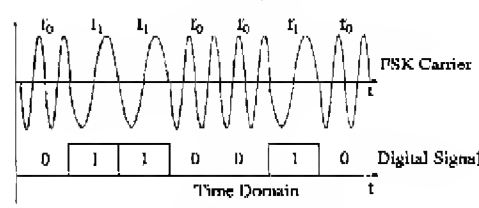
(a)Thompson 2002



(b)Ghovanloo



(c) Young 1978



(d) Ghovanloo